Advanced Information Technology Solutions: An Engine of Innovation

CAR
CENTER FOR AUTOMOTIVE RESEARCH

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Automotive IT Solutions: An Engine of Innovation

Advanced enterprise information technology (IT) solutions are an essential part of managing the increasingly complex automotive industry. These solutions are viewed as a way to intelligently leverage internal and external data sources, transform the brick-and-mortar workplace to the mobile environment, provide real-time collaboration around the world, and free the workforce from the tedious tasks that stifle innovation.

The Center for Automotive Research (CAR) developed this white paper to identify the key market drivers that influence the use of automotive IT solutions, investigate new tools and approaches to IT that address these market drivers, and to evaluate information technology's potential impact on the automotive industry.

CAR's research included interviews with automotive vehicle manufacturers and supplier experts crossing a wide range of activities including manufacturing operations, product development, and supply chain management. Combined with a literature review, several key findings were identified and documented throughout the report. These findings include:

- Complexity with regard to vehicles and the automotive market is placing considerable strain on the resources that are available in the industry and is a source of risk to the end product. These complexities require a systems engineering approach along with a greater emphasis on standards and collaboration both internal and external to an organization.
- The automotive industry places a much greater emphasis on sustainability today than it did 10 years ago. Industry leaders are looking to IT as a way to simulate, monitor, and make decisions on sustainability targets.
- The industry is transitioning from a primarily mechanical-based industry to a software-based industry. In fact, some would argue that the industry is transitioning from a transportation focus to a technology focus.
- Simulation tools are no longer viewed as a support tool and are now used as a primary tool for many development and validation applications.
- Automakers and suppliers are looking for new tools to analyze structured and unstructured data from a variety of sources to improve portfolio planning, quality, and marketing.
- Mobile devices are leveraged more and more as a method to improve communication.

As IT solutions have evolved, automotive executives are looking for IT solutions to create an innovative culture throughout the industry. As one interviewee stated, **"IT is shifting focus to create value for the enterprise through innovation and enterprise collaboration. We are shifting our internal IT brand from a utility to an engine of innovation."**

Advanced Enterprise Information Technology

Today, information technology solutions touch almost every part of the automotive industry. Some of the more prominent IT systems include:

- **Manufacturing operations management (MOM)** – a system of tools to enable end-to-end monitoring and control of manufacturing. These tools manage and execute enterprise-wide manufacturing operations processes, including those associated with production, quality, warehouse, maintenance, labor and the supply chain.
- **Systems Engineering (SE)** – a process and set of tools to manage the complexity of engineering systems over its lifecycle. System engineering tools assist in the definition of customer needs; requirements development and management; design, verification, and validation of the subsystem and system; and assessment for continuous improvement. Systems engineering is an interdisciplinary approach that requires analysis of both business and technical requirements for the system.
- **Supply Chain Management (SCM)** – a system that manages the flow of goods. A wide variety of tools have been developed for supply chain management with functions for planning, sourcing of goods and services, manufacturing the goods, delivery, and return.

Throughout this report several examples of these solutions are represented in various forms. As the industry increases complexity and reduces time to market, these solutions and others like them will only escalate in importance.

Market Trends that Impact IT

Early enterprise information technology solutions focused on reducing time-to-market and development time. Today, these issues are as important as ever; however, utilization of IT tools to tackle these issues have become part of the cost of doing business, not a differentiator. Today, IT solutions are asked to be the backbone of collaboration necessary to overcome the complexity of a global automotive industry.

Intensified interest on sustainability, advances in mechatronic systems, increasingly stringent safety regulations, and consumer interest for connected and automated vehicles are just some of the challenges with which the industry is grappling. At the same time, advances in these areas must be implemented with the same timing, quality, and usability that consumers expect out of the automotive market. Such solutions cannot be delivered without collaboration from all areas of the business.

Throughout a series of interviews, three key trends appeared repeatedly as those that have really changed the landscape of the industry and require a new approach to IT systems. Those trends are:

- manufacturing flexibility,
- sustainability,
- and vehicle electronics.

Market Trends: Manufacturing Flexibility

"The big challenge for us today is to deliver on time what the customer asks. And because the customer asks for a lot of flexibility in the car, each part will be different. We need to deliver to each customer on a case by case basis within 24 hours."

If there were one word to sum up the challenges associated with manufacturing it would be flexibility. There are two forms of flexibility within manufacturing where IT solutions have a role. One form of flexibility requires manufacturing facilities to produce a wide range of parts to meet the customer's needs. To achieve this flexibility, the plant must have the tools and processes in place to accommodate a broad variety of requests. The other form of flexibility is a process in which the underpinnings of the vehicle architecture are communized to achieve economies of scale while still providing the flexibility to accommodate a range of parts that can distinguish one model from the next. Each form of flexibility is a challenge demanding IT systems to help make the right decisions.

Flexible Manufacturing

Flexible manufacturing, where facilities, tools, and processes are developed to accommodate a wide range of products is not a new concept in the automotive industry. The days of being able to get your car in any color you want—as long as it is black—went away a long time ago. One example of flexible manufacturing is the Mazda Skyactiv® engine which is manufactured with Computer Numeric Control (CNC) machines to provide the flexibility to customize engines off the same tool. (Pope, 2013) In this case, the key to flexibility is the ability to make many different parts off the same tool to amortize the tool cost over many parts.

The benefits of flexible manufacturing include nimbleness to meet the changing needs of the customers and to react to regulations; and customization to optimize parts for their specific functions. It is often difficult, if not impossible, to predict the needs of customers. While it is difficult to predict, flexibility allows manufacturers to provide a broader range of products for the customer to choose from. Regulations also have a role in flexibility; crashworthiness and emissions regulations can have a direct influence on the structural design and powertrain decisions of a manufacturer.

The challenge to creating a flexible manufacturing system is having the right tools and processes to achieve the level of customization the customer requires. Not only do the tools need to provide the right level of freedom to produce different parts, but the processes need to be able to sustain that freedom without negatively impacting quality. Advanced IT tools will provide the right information to operators and the right tools to carry out the proper instructions, and parts will need to be sequenced and kitted properly to ensure that the right parts are delivered for the right vehicle, every time.

Flexible Architectures

Flexible vehicle architectures leverage the use of common parts and modules across many models. Certainly the concept of flexible architectures is not new to the industry, but the industry is evolving to provide the flexibility of sourcing common components into a much wider range of vehicle types. One of the most widely publicized introductions of a flexible architecture is the Volkswagen Modular Transverse Matrix platform (MQB). (REUTERS, 2013) Other examples of modular programs in place or in development include the Toyota New Global Architecture, Peugeot Efficient Modular Platform 2, and Nissan Common Module Family. Analysis by IHS and AlixPartners suggests that the top 10 vehicle platforms will represent a total of 202 models worldwide by the year 2017. (Automotive News Europe, 2013)

Benefits of a flexible architecture include the ability to leverage economies of scale for various components; consolidation of engineering resources to develop, test, and validate; and a quick response to quality issues. These benefits can be realized through reductions in material and process costs; and the time to market. For example, Volkswagen estimates a reduction of 20 percent in material cost and as much as a 30 percent reduction in assembly time through the MQB program. (Cremer, 2013)

The move to flexible architectures is not without risk. Commonality of components can limit design freedom and prevent automakers from making products that differentiate themselves from oth-

ers. Commonality can also result in components that are over-engineered for a specific application. Failure of a component in the field can result in massive recalls carrying over to many vehicles and damaging the reputation of the brand. Reliance on globally-supplied goods leaves the industry vulnerable to disruptions such as natural disasters or geo-political conflicts. As the industry moves to a more flexible and global operation IT solutions are being relied on more heavily to identify and mitigate these risks.

The ability to modify a single architecture into many different models in a global environment requires an efficient method for sharing information and data. Enterprise IT solutions are an integral part of enabling automakers to develop platforms that have the flexibility to share common components globally without affecting model features that have regional requirements. For example, regional safety requirements may influence structural elements of a vehicle, but not the common exterior surfaces that are attached to the structure. As the trend toward flexible architectures evolves, IT solutions will be utilized to share more data on common parts, better communicate regional and global requirements, and more quickly identify bottlenecks with existing designs.

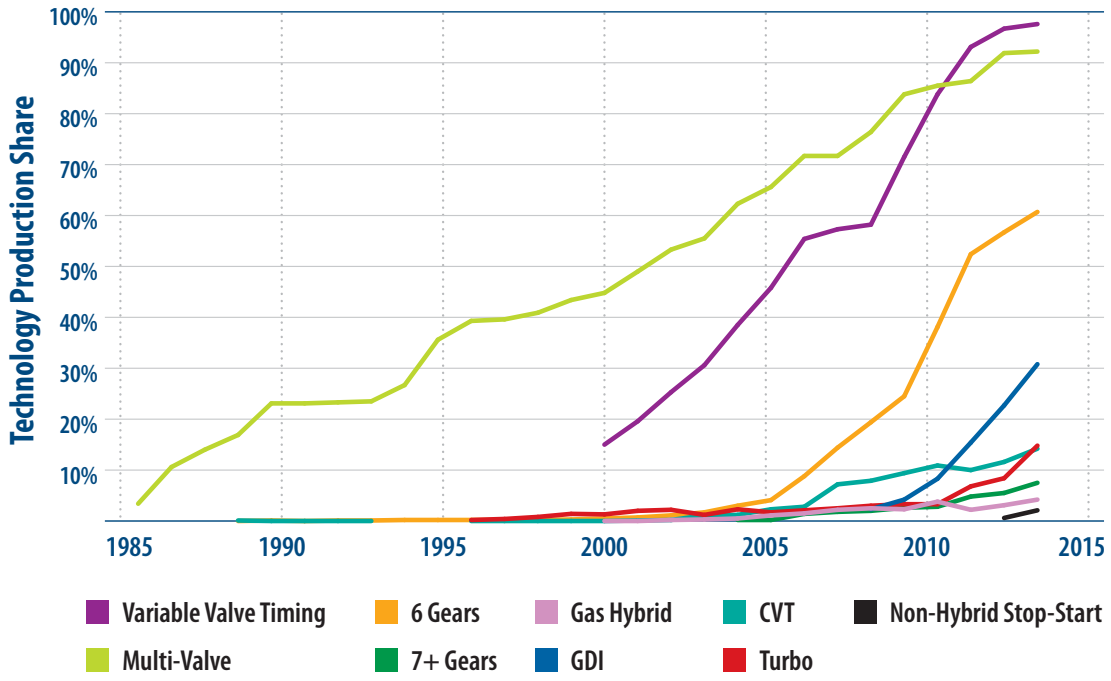
Market Trends: Sustainability

"Ten years ago nobody was communicating on carbon impact; today it is part of our day-to-day communications. In the past 10 years, it is one of the biggest changes in the communication and the way we design products."

Fifteen years ago if asked what the definition of sustainability is in the automotive industry, many executives would describe it as providing a business model that is profitable. Today sustainability has taken on many meanings, from making fuel efficient products; managing the carbon footprint of the supply chain; and yes, long term profitability. For many, the focus on sustainability is based on regulations that are growing increasingly more stringent worldwide, for others the focus is part of an overall corporate culture, and still others see it as an opportunity to drive out waste throughout the supply chain. Many decisions within the industry are based on the sustainability of products or manufacturing processes.

Major changes in fuel economy regulations are taking place throughout the world. To complicate matters, these regulations vary due to many

Figure 1: Market Pentration of Advance Powertrain Technology



Source: Environmental Protection Agency

factors such as vehicle size, type of fuel, and use of advanced technologies. Consumer acceptance is also a significant contributor to the decision process for fuel efficient technology. These changes are driving the industry toward a diverse set of technologies. An example of this rapid shift in fuel efficiency diversification can be seen in the rapid advancement of powertrain technology (Figure 1). The decisions required to meet these objectives and implement technology clearly require a systems engineering approach to planning, development, validation, and manufacturing.

"Increasingly you are seeing sustainability or environmental issues (which were always part of our strategic goal) begin to be operationalized through various types of software and analytical tools. It would certainly be considered systems engineering where it starts with the science and cascades into requirements and tools for planners to meet our sustainability goals."

Automakers are progressively focusing on the carbon footprint of their manufacturing operations, with special emphasis on reducing energy usage. The carbon footprint of assembly processes is directly related to the energy requirements and a reduction is viewed as an increase in efficiency. The manufacturing process of a vehicle accounts for approximately 10 percent of its total carbon footprint. (Das, 2014) As vehicles become more fuel efficient, a greater portion of the overall vehicle life cycle carbon footprint will be the result of the manufacturing process used to make that vehicle. As a result, the carbon footprint of manufacturing is expected to be an even greater focus in the future.

The industry is developing various methods for sustainability and reducing carbon footprint. In discussing this with automakers, they described how internal sustainability targets are being utilized for future vehicle programs. Vehicle programs that do not achieve their goals may pay an internal tax to other programs. In addition, many suppliers now must meet certain sustainability goals or face fines from a vehicle manufacturer for failing to meet key targets. For example, parts suppliers may be asked to achieve a certain weight reduction target. If that target is not met, the supplier may have to pay a fine for every gram the part is overweight. Information technology tools are being developed to take sustainability into account, for example: sustainability metrics are now being built into Computer Aided Design (CAD) tools. The cost/benefit trade-offs must be viewed as a system and include evaluations of regional requirements, consumer acceptance, and supply chain capacity to name a few.

Market Trends: Vehicle Electronics and Network

"If you looked at us 10 years ago we were primarily mechanical business, then we migrated to electromechanical business and now we are primarily software. If you look at the number of software engineers I have compared to mechanical it's probably 20 to 1."

Perhaps nothing is more pervasive in today's automotive industry than vehicle electronics. Just 40 years ago the automobile was virtually devoid of any electronic controls. Now almost 40 percent of the total vehicle cost can be attributed to electronics and vehicle software. (Center for Automotive Research, 2011) Electronically-controlled systems are tasked with controlling almost every aspect of the vehicle. The increased reliance on electronic control systems has led to a significant increase in vehicle complexity and thus risk to the performance of the vehicle. The rapid advancement of electronics and software in the vehicle has made software engineering and integration the number one focus of many automotive suppliers, even those who traditionally made mechanical systems.

Three major changes to automotive vehicle electronics and the vehicle network were emphasized in interviews with vehicle manufacturers and suppliers. These changes are:

- Vehicle computational power has increased significantly, allowing manufacturers to do much more through the vehicle network.
- Infotainment systems are penetrating every vehicle segment and are building in new capabilities every day.
- Connected and automated technology is leading the charge for vehicle safety.

Vehicle Computing Power

Early uses of computers in vehicles, or electronic control units (ECUs), came into being in the late '70s and early '80s as automakers saw the need to improve fuel efficiency and emissions through strict control of engine operations which wasn't possible through mechanical systems. Those early systems typically consisted of one ECU and a handful of sensors to control fuel injection. Today, vehicles have anywhere from 30 to 100 ECUs and monitor thousands of sensors that control almost every aspect of the vehicle. Not only are there more control units, but those control units are becoming much more powerful. Just 10 years ago it was not uncommon to package most of these systems into a 512kbyte microcontroller and even at that size it was unlikely to use all of that memory. The next generation of vehicles is expected to require as much as 8Mbytes of memory to perform all of the functions required.

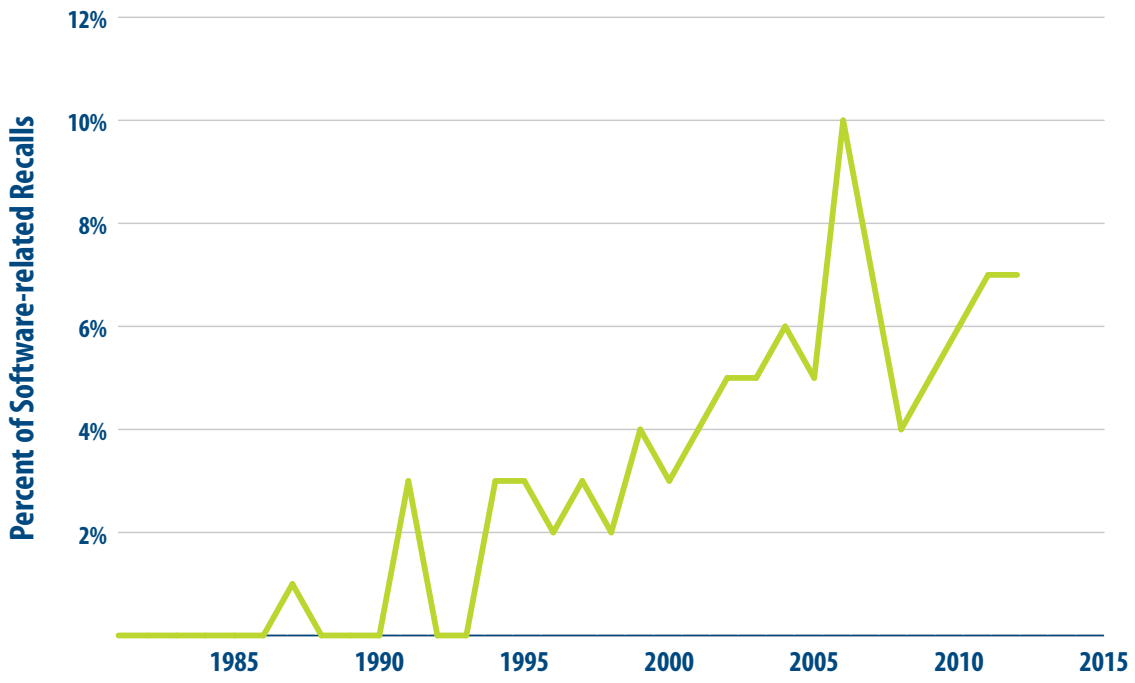
The result of all this computing power is millions of lines of code which must meet specific standards and requirements. Validating those lines of code to ensure that the requirements are met is an area of major scrutiny. Standards such as AUTOSAR and ISO26262 help bridge the gap by defining requirements that are common among vehicle manufacturers. The integration of devices and code from a variety of suppliers and the OEM requires a systems engineering approach to the challenge.

A look at software-related automotive recalls gives a glimpse of the type of risk associated with the rise of vehicle electronics and software code. From the early 80s to today there has been a significant increase in the percentage of software-related recalls in comparison to the total recalls (Figure 2). IT solutions that monitor requirements and standards along with best practices to utilize a robust set of code are primed to help address these challenges.

Infotainment

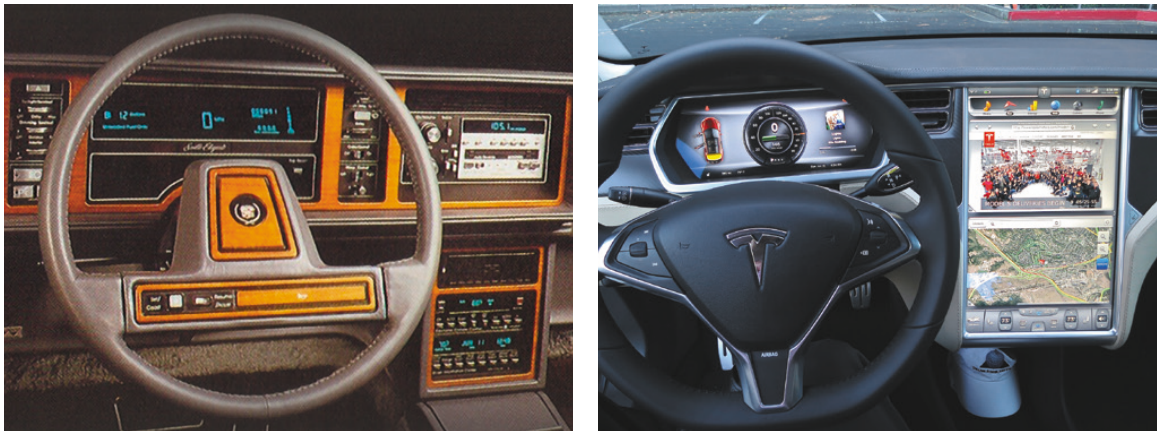
For more than a century, the automobile has been viewed as the device to transport people and goods from one point to the next. With the proliferation of electronics within the vehicle, consumers are expecting a great deal more out of their driving experience. The 1978 Cadillac Seville is regarded

Figure 2: Software specific North American automotive recalls as a percentage of the total recalls



Source: National Highway Traffic Safety Administaration, CAR research

Figure 3: Evolution of vehicle instrument panels—1986 Cadillac Seville (left) and 2012 Tesla Model S (right)



Source: http://www.doubleyoudigital.nl/~cars_digital%20dashboards.php (left), Flickr by jurvetson (right)

as the first American vehicle to offer a full digital display. Rather primitive by today's standards, the Seville's "Tripmaster" allowed the driver to get a display of such things as average fuel economy, remaining range, and engine RPMs. Much has changed since those early days of in-vehicle infotainment systems; a recent global survey by Accenture indicated that in-vehicle infotainment is the primary purchasing decision for 39 percent of respondents compared to just 14 percent for driving performance. (Accenture, 2013) As such, the automotive industry has responded with an astonishing array of infotainment technologies. What initially started as a way to better inform drivers about vehicle performance has quickly evolved into a complete connected experience within the vehicle.

The interaction between the driver and a connected device, such as a smartphone, can provide a great benefit when used properly, but has come under scrutiny with regard to driver distraction. Not only are these systems asked to provide all the usefulness and functionality of the typical mobile device, they are asked to perform those functions while driving a vehicle at 70 miles per hour in traffic. The federal government has regulatory jurisdiction over the technology, but has not enacted any restrictions. The U.S. Department of Transportation (DOT) has promulgated a series of guidelines for the design of in-vehicle electronic devices, but the guidelines are voluntary. (US NHTSA, 2013)

Infotainment acts as a link between the driver and the in-vehicle network. This connection is perhaps one of the more likely targets of vulnerability to the vehicle data network. In 2010, a team of researchers from the University of Washington and the University of California San Diego demonstrated how a vehicle could be compromised by hacking into the infotainment system on certain vehicles. (Checkoway, *et al.*, 2011) The team of researchers was able to gain access to various vehicle controls including the ability to track the vehicle through the in-vehicle GPS and eavesdrop on conversations through the vehicle's speakers. The vulnerability to such systems was found to be incompatibile while trying to integrate various control modules into the entire vehicle network. The growth in the complexity and number of electronics and complexity of software only stands to increase the risk of exploitation. This risk necessitates a systems engineering and PLM approach to communication between vehicle manufacturers and suppliers not common within the automotive community.

Connected and Automated Vehicles

Another market trend that can have a huge impact, connected and automated vehicles, promises to significantly enhance the driving experience with regard to safety and convenience. Leveraging significant advances in wireless technology and sensors along with a rapid increase in in-vehicle computing power, the potential for self-driving vehicles is quickly moving from the realm of science fiction to reality.

Connected and automated vehicles require a level of vehicle awareness that is unprecedented in the industry. Not only must the vehicle monitor its own performance, it must now monitor its entire surroundings. This level of awareness can only be achieved through a sophisticated suite of vehicle sensors and wireless networking capability. The challenges to such a system are numerous, for example: these systems must work under a variety of environmental conditions; must be able to communicate with each other and with the infrastructure; and must provide an interface that is intuitive and distraction free to the driver.

The National Highway Traffic Safety Administration (NHTSA) and the Society of Automotive Engineers (SAE) have recognized a pending need for functional standards related to vehicle automation systems. NHTSA has released a general statement of support for developing the technology and a proposed taxonomy describing functional levels of automation. (US NHTSA, 2013) SAE has released a draft of an alternative taxonomy and is working to provide standards for testing and developing such systems.

Recently, NHTSA has announced via press release that it intends to move forward with a rule-making process to require vehicle-to-vehicle (V2V) communication in future vehicles. (US NHTSA, 2014) Thus far, NHTSA has not published details of a proposed rule in the Federal Register, so it is unknown exactly what the agency will propose. It is widely expected that NHTSA intends to mandate direct short-range communication (DSRC) transponders in future vehicles, using the communication standard SAE J2735 operating on a band at 5.9 Gigahertz that is currently licensed to the U.S. government. At this time it is unclear what the role of automakers will be in deploying and operating a DSRC network to support V2V communications.

The challenges of vehicle electronics and software for vehicle manufacturers clearly require a collaborative environment beyond what the industry is used to. With all of these electrical systems, IT solutions will be necessary to provide the required testing under a wide range of conditions and requirements. The implementation of electronic and software-based systems is growing rapidly in the vehicle. With a system that has been primarily mechanically based for the past 100 years, the industry is scrambling to develop the processes, tools, and workforce to handle the rapid complexity that is being developed. The benefits of electronics and software with regard to the interaction with the customer are numerous, but this interaction comes with a host of new problems not typically experienced by the industry. Research into driver distraction, ease of use, and network security are emerging areas of interest in the automotive industry and will require IT solutions to tackle these issues.

Opportunities and Challenges

With resources strained, vehicle complexity at an all-time high and increased emphasis on integration between suppliers and vehicle manufacturers, communication is a key requirement in the industry. Interviewees identified several new approaches and one key challenge to facilitate communication, free up resources, and improve the analytical capabilities across several areas of the automotive industry. The opportunities most often identified by interviewees were:

- Mobile devices
- Cloud computing
- Enterprise social networks
- Big data
- Simulation tools

On the other hand, legacy systems were identified as the biggest challenge to the implementation of most advanced IT solutions. Certainly where there are no legacy systems already in place it is much easier to implement new solutions.

As the industry continues to evolve, new IT implementations will need to be weighed against the infrastructure already in place, cost to implement, and value gained. The following section describes some of the key opportunities identified by interviewees and the challenge of implementing these new systems.

Mobile Devices

"Our program allows employees to become more mobile, to access high-quality digital information and services anywhere, any time, on any device."

Mobility in the workplace was identified as a key tool for many interviewees. As mobile devices become more powerful and popular, companies are looking to leverage this technology to provide access to the workplace from anywhere. Global IT systems trying to leverage mobile devices are discovering new opportunities and challenges with implementation. With the integration of mobile devices, companies are learning new ways to leverage their unique capabilities and pushing the bounds of their limitation.

In 2007 Apple introduced the iPhone and almost overnight the age of mobile computing was born. The use of mobile devices has skyrocketed in recent years. Smartphone ownership of adults is estimated to have grown from 35 percent in 2011 to 55 percent in 2013 and tablet ownership has increased from 2 percent to 42 percent over the same time period. Of adults with a college education, 69 percent own a smartphone. (Pew Research, 2013) Not only are mobile devices being adopted at an incredible rate, people are becoming more and more reliant on their use for everything they do. A report by the International Data Corporation indicates that 79 percent of smartphone owners check their phone within 15 minutes of waking up; that percentage increases to 89 percent for adults between the ages of 18 and 24. In addition, a majority of individuals have their smartphones on or near them for all but two hours of their waking day. (IDC, 2013) With the rapid growth of smartphone and tablet use, particularly among college-educated individuals, it is no wonder that automotive companies are grappling with ways to leverage such mobile devices in the work space.

Examples of opportunities that can be realized through mobile devices include managing engineering change processes, visualizing CAD files, viewing plant maintenance procedures, and viewing service procedures. Cloud-based office programs like Google Docs are making it possible to work on simple word processing and spreadsheet applications collaboratively and from almost anywhere. In the future, mobile devices may be leveraged more for their enhanced capabilities over other devices. For example, augmented reality could be used to help service technicians locate parts and view virtual components as if they are on the vehicle. Plant floor operations may be able to monitor the steps an operator takes per job by monitoring the accelerometer and gyroscope data available on smartphones. For now however, the direction of mobile IT is primarily limited to existing job functions and making existing data available to the mobile environment.

While there is certainly an opportunity and desire to leverage smartphones and tablets in the workplace, there are challenges and limitations to their implementation. With any "bring your own device" (BYOD) strategy, security is a primary concern for enterprise applications. This is particularly true within product planning and product development, where corporate strategy and key vehicle attributes are defined and executed. Another challenge of mobile devices is the form factor. Small screens and a lack of peripheral devices such as key boards can make usability a challenge for some applications. As the industry moves forward with mobile device integration, these concerns and limitations will continue to challenge mobility in the work place.

Cloud Computing

"Our entire work environment has been virtualized so that we can work from anywhere."

As the industry moves to a more global operation, cloud computing is looked at more and more as a tool of collaboration and around-the-clock operations. According to research conducted by KPMG (KPMG International, 2013), 70 percent of IT professionals believe that cloud-based services are delivering on efficiency and cost-saving measures. Traditional uses for cloud computing in the automotive industry include supply chain management, parts and logistics, and dealer management systems.

More recently, cloud-based systems are being developed for product lifecycle management (PLM) systems allowing vehicle manufacturers and suppliers to work collaboratively on designs in real-time. (Gould, 2014) With vehicle complexity on the rise, engineering resources are limited in

the various options that are available. Increasingly, automakers are looking to leverage engineering expertise worldwide to handle this complexity.

Manufacturing operation management systems are also seeing benefits through the use of cloud based systems. By leveraging the increased processing power of a cloud based system, manufacturers can perform advanced analysis of plant scheduling and material logistics. Cloud computing also enables operations to centralize plant data so that complex analysis may be performed for root cause analysis and to test solutions.

While PLM and MOM vendors now offer cloud-based solutions, the industry has been reluctant to adopt such solutions. The biggest concern with regard to PLM cloud computing is security. While security is always a primary concern of cloud computing, this is particularly true of PLM solutions where much of the core product intellectual property resides. Another challenge to cloud-based PLM and MOM is the legacy systems that are already in place. These legacy systems are typically very large, on-site IT systems that have taken considerable investment, including time and talent spent learning and using these tools. Changing PLM and MOM systems, much less to a cloud-based systems, is a challenge to justify in many cases.

The benefit of a cloud-based enterprise IT solution is the ability to access data and applications from virtually anywhere. In addition, it provides a scalable, centrally located infrastructure which can increase IT efficiency and reduce infrastructure costs. Challenges with legacy systems and information security still limit the penetration of cloud systems for automotive applications. In the future, it is expected that the industry will continue to move forward with cloud-based systems incrementally.

Enterprise Social Networking

Social networking sites are popular in part because they provide an easy, intuitive way to share information with others. The success of social networking has left many in the industry wondering if it is possible to use this technique to improve internal communications. As Steve Kang, social enterprise manager for Toyota points out, "Most of the knowledge is tacit. It is walking around in the heads of our employees. The question is how do you get that knowledge? How do you extract that knowledge, because it's not written down anywhere?" (Automotive News, 2012)

Examples of enterprise social networks such as GM's OverDrive, Toyota's Chatter, and Ford's Yammer already exist in the workplace. Such tools are typically used for quick communication and to get feedback from a large network of employees. In addition to quick communication, enterprise social networks act as a conduit to enable employees to see the big picture of their organization and to interact with a broader workforce.

While enterprise social networks can streamline communication, they do have some challenges. As with public forums and social networks, with such a broad user group, social networks are prone to noise from its users. A single question can generate many responses with no way of telling which answer is the best or if any answer is correct. Questions to problems may be asked multiple times to the annoyance of other users. Questions may be buried by other, more popular questions. Clearly an IT solution which addresses these issues could efficiently tap a wealth of knowledge.

Big Data

"It looks like it can be a revolutionary approach to managing the very diverse data sets that we have. Traditionally the data sets have been very rigid and difficult to use. Someday we expect to handle very disparate data sets through a big data appliance to do analysis without needing to clean the data."

Data is everywhere in the automotive industry. Internal to a company, product planners conduct market studies to determine the next generation of vehicles; development and validation engineers conduct hundreds of tests to ensure the safety and performance of new vehicles; manufacturing engineers validate new tools prior to the launch of a new vehicle; manufacturing plants routinely verify part and assembly quality throughout the day; and materials, parts and subassemblies are tracked to ensure just-in-time delivery and installation. Other data outside of the company that can be leveraged include vehicle repair history tracked through the dealer network; connected vehicle technology lev-

eraged to collect usage and performance data; and blogs used to monitor perception of products. One of the richest data opportunities in the automotive industry is the connected vehicle. IHS estimates that 480 terabytes of data was collected by vehicle manufacturers in the year 2013 alone and estimates the industry will collect 11.1 petabytes of data by the year 2020 for connected vehicle data. (IHS, 2013) The automotive industry is looking for opportunities to leverage this data for use with current and future products.

A significant challenge to big data is providing tools that are easy enough to use for the people that need to use them. Often those who know how to use the tools are not the ones who are able to make decisions. For the value of big data to be fully realized, the tools must be made simple enough for the analysts to use directly.

As more data becomes available, the advantages of big data will become even greater. Almost every part of the automotive supply chain can benefit if big data can be harnessed successfully. However, those benefits must be weighed against the risk that is associated with the collection and analysis of such data. Further, the tools to do the analysis require specialized skills to identify and interpret the data in a meaningful way.

Simulation Tools

"We're moving away from physical prototype builds to simulation in everything we do."

Simulation tools have advanced significantly over the past 20 years. Once thought of as a tool used by a select few engineers to assist with development of vehicle prototypes and by validation engineers during product development, simulation tools are now looked at as the rule rather than the exception.

During the '90s a traditional automotive program would require more than two prototypes and no virtual prototyping between the "styling freeze" and start of production. The typical timeframe to carry out such a product plan ranged anywhere from 40 to 52 months. The early 2000s saw a reduction of the number of physical prototypes with the introduction of virtual prototypes. As a result, the time between styling freeze and start of production was reduced to an average of 24 to 30

months. (Sippel, 2008) However, the traditional method of product development still consisted of design, analyze, build and test. This approach pushes much of the product knowledge later into the product development process, limiting the freedom to make decisions to change the product.

"We used to do a lot more physical testing than we do now. The wave of the future is that we don't do prototype builds anymore. They used to say it's too expensive to do simulation now they say it's too expensive not to simulate."

Today, simulation tool capabilities have advanced significantly so it is no longer necessary to follow the traditional methods of product development, allowing engineers to experiment with innovative technologies earlier in the development process. A major thrust of simulation is frontloading of vehicle programs. The most cost-effective time to consider new and innovative technologies is during the architecture planning phase of vehicle development. By front loading programs with data from previous projects, review boards have more flexibility to evaluate and introduce innovative technologies.

Simulation tools will continue to expand into new areas as computing power and data become more available. As the industry moves to more complex systems, specialized tools for material fabrication, energy modeling, electrical system interaction, and safety performance will be required. Simulation tools can test scenarios that might be difficult or impossible to conduct in a typical test environment. With physical testing resources strained and significant advancements in simulation tools, simulation tools will be leveraged more often for providing the primary analysis of systems.

Legacy Systems

The one challenge identified by virtually every interviewee was the use of in-house legacy systems. Often these systems were put in place to perform a specific function within the company and replacing these systems is often perceived as a compromise at some level on the functionality of the systems even if the overall functionality increases and improves. In addition, if the replacement of such systems does not work as planned it may result in the disruption of work and loss of revenue.

Legacy systems have a host of risks as well. Legacy systems are often not standardized with other legacy systems resulting in added support cost to maintain and manage. Aging systems may lack the support from both internal and external sources as those familiar with the system are no longer in the industry.

The industry is taking a gradual approach to replacing legacy systems with standardized data systems. Most survey respondents felt that there is some compromise with regard to the functionality of these standardized systems and that instead of the 100 percent functionality of legacy systems, some functionality will need to be built into a custom solution or eliminated from the standard operating procedure. One respondent suggested, "In some cases we're leading the way and need to find a way to implement it into the system. For others, we built systems that were a special request that is no longer applicable or efficient. You really challenge your own internal processes to determine if our process is critical." (CAR Interview, 2014) New IT solutions are responding to this challenge by offering standardized tools that offer the flexibility required for their commercial application.

Implications of Next Generation IT

The next generation of IT solutions impact almost every part of the automotive industry. At the same time these solutions create new challenges which must be managed. Interviewed experts provided an array of examples of current and future benefits from IT solutions. These examples included changes to operation in manufacturing, product development, supply chain management and logistics, service operations, customer management and dealer management systems. At the same time, changes in the workforce and challenges with regard to consumer privacy were key concerns of interviewees. The following section describes how IT solutions impact many segments of the automotive industry as well as consumers who buy and drive automobiles.

Manufacturing

The manufacturing environment which was once dominated by green screens and clip boards is transforming to a sophisticated work setting where data is transferred throughout the plant and the entire global organization.

Work instructions and best practices, which were laminated and chained to or above a workstation, can be displayed on a full color screen with step by step instructions. As the operator works, the screen updates itself with the proper instructions for that job. A visual representation, using math data that was provided by manufacturing engineers, of the part and process are displayed for the operator in real-time.

The time-consuming process of collecting data machine by machine, then analyzing the data could become a thing of the past. With a fully integrated system, data could be collected and stored centrally for viewing at any time and at any place in near real-time. Where in the past, monitoring of a particular station may happen every few days; a centralized solution could make it possible to view the real-time status of the entire plant at any

time. Today, advanced analytics tools may make it possible to get automated reports of critical manufacturing data whenever it is needed. One interviewee envisioned a future in which a manager would wake up and receive a full report of all the plants via smartphone without the need to request a report. He will be surprised to know that this is available today.

Flexible manufacturing, which enables a plant to produce many different components, subsystems, and full systems, will continue to improve as IT solutions advance. Manufacturing simulation tools that create what-if analysis will continue to evolve for a greater number of scenarios.

The evolution of manufacturing IT solutions is poised to impact everyone who is involved with the manufacturing process. Plant floor workers will receive work instruction in real-time as they are doing their job. Plant engineers and managers will be able to analyze and manage the plant without needing to manually collect data. Manufacturing engineers will be able to simulate new processes and plant layouts to provide the most efficient and flexible manufacturing system possible. Many of these IT solutions are available today and are finding applications in facilities throughout the industry. The vast improvement of manufacturing IT systems will only improve as tools integrate more closely to provide a closed-loop global manufacturing system.

Product Development

"Complexity of the trade-offs today are so immense. Given how complex the systems are, having these fast computers and sophisticated algorithms is really helpful, and we're going to see more emphasis on optimization from a systems approach. It wasn't possible to do this in the past."

Increased vehicle complexity due to the demand for better fuel economy, safety, and vehicle electronics are straining the resources of the product development community. An ever-expanding list of new technologies must be tested and validated to ensure their operation in service. At the same time, physical testing will continue to be reduced in an effort to decrease cost and time to market. IT solutions and a systems engineering approach are being relied on heavily to make such scenarios possible. Advances in IT solutions promise to improve product development by:

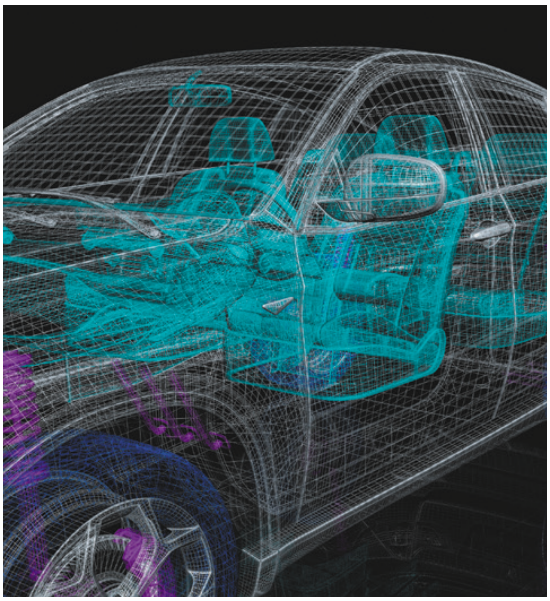
- Enabling around the clock collaborative engineering
- Leveraging simulation for a greater range of technology and test scenarios earlier in a vehicle program
- Empowering engineers to communicate and access data in real-time from anywhere
- Providing engineers with access to a greater amount of real-world test data to improve developing and future products
- Facilitating the ability to test systems and sub-systems from virtually anywhere

"We are now managing everything from concept to end of production. We used to throw it over the wall to production to manage but that's not how it is now. We manage everything from requirements to simulation to test data."

Greater emphasis on collaboration both within an individual company and between suppliers and vehicle manufacturers will be necessary. Concurrent engineering, where work on a product is continuously worked on throughout the day from different regions still eludes the industry. However, the industry has already shown progress when done on a smaller scale within a geographical region. As the tools continue to develop it may be possible to finally achieve this goal.

Simulation has become a key differentiator within product development. New tools are going to be needed to deal with many new and unproven technologies. For example, the field of materials formability modeling is still evolving. Automakers are rushing to make safer, lighter weight cars that will push the envelope of the type of materials used in vehicles. The performance of these materials is often not well known to the engineers who must implement them. As new technologies are pushed into the market, specialized simulation tools are a critical requirement within the industry.

With mobile devices becoming more prevalent and more powerful each day, product development is poised to leverage such technology more and more within the workplace. Visualization of data is possible today with off-the-shelf solutions; it is



quite possible that in the future, engineers will be able to modify components in real-time from their devices. Status updates and requirements tracking are almost a given with today's devices, making much of the work that engineers do today accessible from almost anywhere.

In-vehicle data collection of the past required equipping a vehicle with a data logger and several sensors. The data would be stored locally to a computer and analyzed by an engineer with access to that computer. Limitations to hardware and analytical capability of the engineer would often limit the amount of data collection possible under such a work environment. In addition, an engineer or technician would physically determine when to start and stop collection of data. By utilizing connected vehicle technology and the sensors on the vehicle, data can be collected remotely anytime and anywhere. Not only can data be collected at any time, but the capacity to store data has increased significantly. In the short term this is expected to create a challenge to the industry as there is so much data it will be difficult to understand what is important and what is not. However, as analytical tools increase in capability, much of the manual analysis that was required could go away. In the long term, tools that collect and analyze data are expected to significantly reduce the burden of testing and allow decision makers to spend more time focusing on the value of the product.

Product development will continue to evolve dramatically through IT solutions. As the automotive market becomes more complex, IT solutions will need to employ a systems engineering approach to improve communication globally, monitor requirements and specifications, perform what-if analysis on a variety of parameters, simulate a growing number of technologies, and reuse information from existing programs. Perhaps the most important benefit of these solutions is their potential to evaluate a greater number of innovative concepts early in the program when there is flexibility to make major changes.

Supply Chain

A big area of concern is the fragility of the automotive supply chain with regard to disruptions. The economic recession of 2009, Iceland volcanic eruption of 2011, Tokyo Tsunami of 2011, and fire at the Evonik Industries chemical plant in 2012 all serve as examples where a local catastrophe resulted in a global disruption of the automotive supply chain. As the automotive industry continues to move toward globalization, it will only become more susceptible to local risks affecting the global supply chain.

A key enabler to mitigate this risk will be through the use of what-if analysis of the supply chain to a variety of disruptions. By using risk analysis, companies are able to identify and mitigate or eliminate weak links in the supply chain. Companies will also be able to use the risk analysis to create procedures in the event that a major disaster should occur. To successfully analyze the supply chain risks, IT solutions will need to be utilized to provide greater visibility to sub-tier suppliers.

Another area where advanced IT solutions are improving supply chain management is in the development and design of shipping containers. Just as the automotive industry is moving to greater flexibility in its manufacturing processes, packaging containers must also provide greater flexibility to accommodate a more diverse set of components. Computer aided design and engineering tools hold the potential to develop shipping containers that increase packaging density, reduce overall material cost, reduce weight, and support a wide array of components. These tools will also enable engineers to test these containers virtually for a wide range of loading, unloading, and transport conditions that traditionally required physical prototyping. (Ogle, 2014)

Service Centers

IT solutions will have a significant impact on the automotive service industry. As IT solutions become more centralized and data becomes more visible, the opportunities for the service industry include reductions in service parts inventory, obsolescent parts, and referral costs, as well as an increase in forecast accuracy.

The relationship between consumers and the service industry is primed for significant change through IT solutions. With the advent of connected vehicles and an archive of vehicle history, service centers can be notified in advance of vehicles that need servicing or may need servicing soon. Parts could be ordered before a customer even realizes his or her vehicle needs servicing. At the same time, the customer can be notified of a potential issue via text or email and directed to a service center equipped to perform the necessary maintenance. This opportunity can smooth the relationship between dealers and their customers and differentiate the dealership from other service centers.

Advance IT tools also have the opportunity to improve the work environment for service technicians. Augmented reality combined with visualization tools provided by the manufacturer will enable service technicians to not only look through a set of instructions but actually see the instructions overlaid on the actual vehicle through use of a mobile device and its camera. In addition, with ERP systems, service centers are able to identify every part on a vehicle through a single system enabling service centers to order the right parts for each vehicle.

By utilizing IT solutions, service centers will continue to improve inventory management; however, a greater opportunity exists with how the centers can interact with their customers. By using IT solutions, service centers may be able to plan and predict when and what repairs are necessary. In addition, these solutions can improve the work environment of technicians through better visualization of work instructions.

Marketing

Data that can be used to shape marketing plans and tailor campaigns to individual buyers is everywhere today. Blogs, cookie tracking, search engine marketing and analysis, social networks, online business directories (such as jigsaw), and application programming interfaces (APIs) are a few examples of the new data sources that are available for marketing purposes. Combining this with data from dealer networks, focus groups, and connected vehicles, product planning and corporate strategy groups have mounds of data at their disposal. This structured and unstructured data was historically difficult to analyze and manage. However, a combination of CRM and big data sources are making it possible to easily extract data and then analyze. As these tools become more sophisticated, the automotive industry will be able to understand and market to their consumers in a far more efficient and effective manner.

Behavioral psychology, along with advanced analytics, is paving the way to a new era of marketing where ad campaigns are not only reactive but proactive in nature. Target, for example, has used the purchasing history of its customers to identify and advertise to expectant mothers. (DUHIGG, 2012) Those key moments when people undergo life event changes are a critical moment when purchasing habits change. A move to a new city, expecting a baby, graduating from college, and getting a new job can all be events that trigger the purchase of a new vehicle. Leveraging big data through the effective use of IT is enabling the automotive industry to predict such events.

Yet, there can be many challenges to collecting such data. Dealerships, out of concern for providing sensitive customer data, may be hesitant to provide data to a manufacturer. (Automotive News, 2014) As a result the National Automobile Dealers Association has published guidelines on how to share sensitive data with vehicle manufacturers. In addition, dealers often see this data as a competitive advantage over others and are less willing to hand the data over.

Through the use of big data there are clear opportunities to enhance consumer marketing efforts. However, with this data there is the potential to alienate customers and cause friction between the marketing departments and those who have ownership of the data. If these issues can be managed properly, marketing departments will have a far greater understanding of who their customers are and what they respond to.

Consumer Data Privacy

With the advent of connected vehicles, access to user data has never been higher. Traditional vehicle data along with GPS can provide an automaker tremendous access to a user's driving history. Until recently, consumers were either unaware or somewhat accepting that data was being collected. However, recent events have placed a laser focus on the collection of data in all forms of media of which the in-vehicle connected system is just one. The topic of data privacy is at an all-time high both in the public conscience and the media. The unveiling of data collection tactics used by the National Security Administration seemed to incite a reaction among the public on what is collected, who is collecting it and for what purpose. With the potential benefits of user data from connected vehicles, balancing the collection of data and the ways in which it is used is a looming issue in the automotive industry.

With the growing popularity of infotainment and connected vehicle technology, the automotive industry is under considerable scrutiny with regard to vehicle data collection. For example, a simple change to the OnStar privacy policy in 2011, "There may be instances where we sell some or all of our business operations," created considerable backlash that resulted in the company's retraction of the policy change. More recently, Jim Farley, executive vice president of Global Marketing, Sales and Service and Lincoln for Ford, commented that "We know everyone who breaks the law, we know when you're doing it. We have GPS in your car, so we know what you're doing. By the way, we don't supply that data to anyone," creating several headlines and also requiring a retraction stating, "We do not track our customers in their cars without their approval or their consent," he said. "The statement I made in my eyes was hypothetical and I want to clear this up." As customer data becomes more pervasive vehicle manufacturers must carefully balance the benefits of using the data against the risk of public scrutiny.[1]

Workforce

It's been said that Tesla considers itself a technology company, not an automotive company, and without a doubt the entire automotive industry is moving more towards becoming a technology industry in addition to a transportation industry. In virtually all instances, software is the key focus of suppliers and manufacturers. What was once a primarily mechanical engineering driven workforce has shifted dramatically to a mechatronics and software engineering workforce. With some major suppliers, as much as 80 percent of the value added work is done through simulations. (CAR Interview, 2014)

An example of this transition can be seen at General Motors where the outsourced IT department has been replaced by the hiring of approximately 9,000 direct IT employees. Randy Mott, Chief Information Officer of General Motors stated, **"to transform the company, you really need IT, which touches all parts of the business."** (Rosenbush, 2013)

With most interviews, the introduction of new tools was met with hesitation from users. Reasons for hesitation included:

- Compromises with regard to functionality – The tools are now standard but some of the customization of legacy tools was lost
- The software is too challenging and requires special training to use properly
- General resistance to change

Often, these IT systems would be replacing tailored systems that had been developed in-house or by a third party that performed 100 percent of the functionality required to complete a job. However, when introducing a new system designed to be common corporate wide, some of that functionality is lost and must be performed manually. While real benefits to the system exist, the behind the scenes benefits of reduced infrastructure and maintenance cost were not visible to the user.

Possibly the most referenced workplace challenge to the use of new IT solutions was the difficulty of using the tools. In many cases the people most capable to use the software were not the people who would benefit the most from the tools. For example, big data solutions would best be used by those who know how to analyze data to observe and make decisions based on trends found in the data. However, the difficulty with which to use

[1] *CAR has addressed ethical aspects of government use of connected vehicle data in (Hong, Cregger, & Wallace, 2012) and is currently working on an update to this research that should be available later in 2014.*

those tools may require someone who has more database experience.

On the other hand, if done well, such tools can provide a positive user experience. One respondent commented on how their manufacturing operations solutions actually improved the workplace environment and is now a tool that is requested at plants throughout the corporation. This sentiment was shared by several of the respondents.

As can be seen throughout the report, the workforce will be affected in many ways by IT solutions. Many of these effects are seen as a challenge; however, if done properly, they may also make the entire work process more efficient. One of the big challenges of IT solutions will be to make systems that not only improve workflow, but do it in a way that is easy and accessible to the user.

The Integration of Systems

While there have been significant advances in IT solutions, it was surprising that interviewees struggled to provide examples of integration between software systems and automotive divisions. In most cases, there was limited understanding with regard to how portions of an organization influence the other parts of the business. In that sense, it appears that the industry still operates much of its business as silos.

While this lack of integration across areas may be partially true, there have been significant advances within each domain. Manufacturing systems are moving away from green screen technology to fully visual and integrated systems that provide visibility throughout the manufacturing process. Product development, no longer able to take a component level approach to engineering, is transitioning to a systems engineering approach where engineers consider how each component impacts the vehicle as a whole. Supply chain systems are moving to a more globally focused operation and leveraging assets throughout the world. Interviewees described the progress in each of these domains, and it was apparent that there is some coordination, but the linkage was subtle enough to not be noticed by everyone. The next generation of IT solutions has a prime opportunity to provide greater integration of systems and to leverage the assets of the industry fully.

Conclusions

The automotive industry has made great strides to improve the quality and performance of its vehicles throughout the last 40 years. Vehicles are safer; more fuel efficient, powerful and reliable; and include a host of new technologies that make driving more enjoyable. At the same time the industry has increased workforce productivity, reduced waste, and improved time-to-market. Throughout this transition, advanced enterprise information technologies solutions provided the backbone of these improvements. As the automotive industry challenges continue to escalate, even more advanced IT solutions will be required.

The automotive industry and the environment in which it operates are not standing still. Key challenges to the industry that were identified during this study are:

- Complexity driven by safety and fuel economy regulations, demands for vehicle electronics, and the acceleration of the number of vehicle models is placing considerable strain on the resources that are available in the industry and is a source of risk to the end product.
- New skills are required of the workforce as the industry transitions from primarily a mechanical based industry to an electrical and software based industry.
- Legacy systems make the transition to the most advanced and connected IT solutions difficult. At the same time, legacy systems are a risk as well due to limited resources to maintain them.

A common theme throughout the report was that communication and collaboration are key to resolving the industry's biggest challenges. As these challenges accelerate, the automotive industry is utilizing more advanced enterprise IT systems to foster this collaborative work environment. These systems are focused on:

- Manufacturing engineering systems that enable plant operations to see results from the plant floor in real-time, visualizes manufacturing processes for line workers, and stores data to be analyzed whenever needed.
- Systems engineering tools such as product lifecycle management that enable engineers to adhere to global and local specifications, provide visibility to product teams on the progress of a program, and enable engineers to treat the vehicle as an entire system as opposed to the silo approach of the past.
- Simulation tools that have developed beyond the point to which they are viewed as a support tool and are now used as a primary tool for many development and validation applications. Simulation tools are being used to improve logistical issues by modeling crate designs that are robust for transportation, flexible enough for multiple parts, and increase packing density.
- Supply chain tools that enable manufacturers to plan for and mitigate potential supply chain risks in the event of a global disruption and evaluate the cost/benefit of flexible systems.

As the automotive industry becomes even more complex and new challenges arise, IT solutions will need to continue to evolve as well.

Bibliography

Accenture. (2013, December 2). *Connected Vehicle: What Drivers Want*. (Accenture) Retrieved Dec. 3, 2013, from http://newsroom.accenture.com/article_display.cfm?article_id=5919

Automotive News. (2012, August 18). *Automakers tap internal social enterprise tools to mine employee expertise*. Retrieved January 2013, from http://www.autonews.com/article/20120818/OEM/120819867/automakers-tap-internal-social-enterprise-tools-to-mine-employee

Automotive News. (2014, February 24). *Jag wants customer data irks its dealers*. Retrieved February 24, 2014, from http://www.autonews.com/article/20140224/OEM06/302249973/jag-wants-customer-data-irks-its-dealers

Automotive News Europe. (2013, June 6). *VW extends lead in common architectures -- but there are risks:*. Retrieved June 6, 2013, from http://europe.autonews.com/article/20130606/ANE/306079998/vw-extends-lead-in-common-architectures----but-there-are-risks

(2014, January 28). CAR Interview.

(2014, February 20). CAR Interview.

Center for Automotive Research. (2011). *Automotive Technology: Greener-Vehicles, Changing Skills - Electronics, Software and Skills Report.*

Checkoway, S., McCoy, D., Kantor, B., Anderson, D., Shacham, H., Savage, S., . . . Kohno, T. (2011). Comprehensive Experimental Analyses of Automotive Attack Surfaces. *USENIX Security.*

Cremer, A. (2013, October 28). *VW's 'new era' vehicle platform seen putting a drag on profits*. Retrieved from Reuters: http://www.reuters.com/article/2013/10/28/us-vw-results-idUSBRE99R0UT20131028

Das, S. (2014). *Life Cycle Assessment - Energy and CO_2 Emissions of Aluminum-Intesive Vehicles.* Oakridge National Laboratory.

DUHIGG, C. (2012, February 16). *How Companies Learn Your Secrets*. (New York Times) Retrieved September 2013, from http://www.nytimes.com/2012/02/19/magazine/shopping-habits.html?pagewanted=all

Gould, L. (2014, Febuary). Dassault Goes To The Cloud. *Automotive Design and Production*, pp. 34-35.

Hong, Q., Cregger, J., & Wallace, R. (2012). *Ethics of Government Use of Data Collected Via Intelligent Transportation Systems.* Center for Automotive Research.

IDC. (2013). *Always Connected: How Smartphones And Social Keep Us Engaged.* Retrieved January 2014, from https://fb-public.app.box.com/s/3iq5x6uwnqtq7ki4q8wk

IHS. (2013, November 19). *Big Data in the Driver's Seat of Connected Car Technological Advances - Yahoo Finance*. Retrieved December 2013, from http://finance.yahoo.com/news/big-data-driver-seat-connected-140000995.html

KPMG International. (2013). *The cloud takes shape.* KPMG INternational.

Loverde, L. (2013). IDC Forecasts PC Shipments to Fall by Double Digits In 2013; Volumes Are Expected To Stabilize Above 300 Million Units per Year, But With No Significant Recovery . FRAMINGHAM: IDC.

Morgans, S. (2012). Advanced High-Strength Steel Technologies in the 2013 Ford Fusion. *Great Designs In Steel.* Livonia.

National Geographic. (2001, September 11). *Surgeons in U.S. Perform Operation in France Via Robot*. Retrieved January 2014, from http://news.nationalgeographic.com/news/2001/09/0919_robot-surgery.html

Ogle, S. (2014, January 14). *Virtual technology the next frontier in packaging*. (Automotive Supply Chain Magazine) Retrieved from http://www.automotivesupplychain.org/features/228/79/Virtual-technology-the-next-frontier-in-packaging/

Pew Research. (2013, September). *Pew Internet: Mobile | Pew Research Center's Internet & American Life Project*. Retrieved December 2013, from http://pewinternet.org/Commentary/2012/February/Pew-Internet-Mobile.aspx

Pope, B. (2013, October 11). *Mazda Rethinks Manufacturing Process*. Retrieved from Wards Automotive: http://wardsauto.com/auto-makers/mazda-rethinks-manufacturing-process

REUTERS. (2013, October 28). *Volkswagen MQB platform fails early to meet lofty expectations - Newsday*. Retrieved October 2013, from http://www.newsday.com/classifieds/cars/volkswagen-mqb-platform-fails-early-to-meet-lofty-expectations-1.6334421

Rosenbush, S. (2013, May 15). *How GM Lost a Mainframe, But Gained an IT Department*. (The CIO Report - WSJ) Retrieved January 2014, from http://blogs.wsj.com/cio/2013/05/15/how-gm-lost-a-mainframe-but-gained-an-it-department/

Sippel, H. (2008). CAE at Different Stages In Product Development. *AutoSim Webinar.*

US NHTSA. (2013, May 30). *U.S. Department of Transportation Releases Policy on Automated Vehicle Development* . Retrieved from http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development

US NHTSA. (2013, April 23). *U.S. DOT Releases Guidelines to Minimize In-Vehicle Distractions*. Retrieved from http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+DOT+Releases+Guidelines+to+Minimize+In-Vehicle+Distractions

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